Vibration Free Sorption Cryocoolers for Astrophysics Applications

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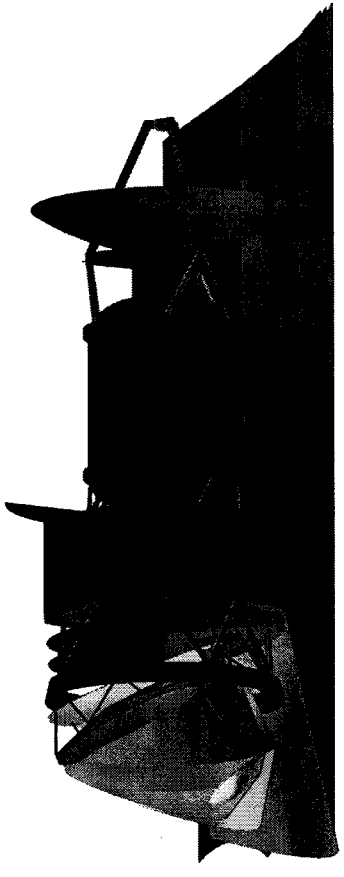
Mission Applications



Concept drawing of FIRST/Planck combined mission. Radiation shields cut away to show telescope details.

Hydrogen sorption cryocoolers baselined on Planck Surveyor cosmic microwave background mission.

- 20 K cooling of HEMT detectors on Low Frequency Instrument
- 18 K precooling of 100 mK High Frequency Instrument stage.

Sorption cryocoolers are strong candidates for future missions with infrared and microwave detectors.

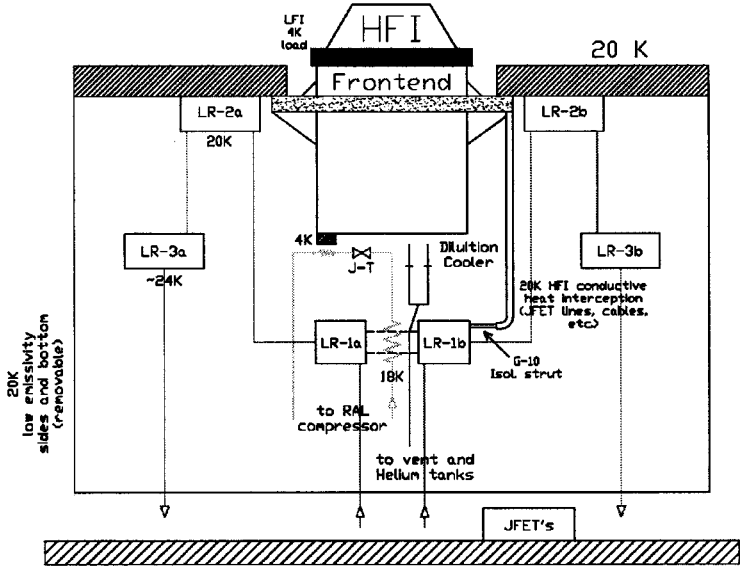
- NGST - detectors cooled to <30 K and 6 - 8 K.
- ARISE - detectors cooled to <16 K.
- HTXS - detectors cooled to 1.5K.
- TPF - detectors cooled to 4 - 6 K

Accelerated development of miniature cryocoolers would allow missions to adopt the technology for Midex, SMEX, and/or ESSP competitive proposals and other platforms as opportunities become available.

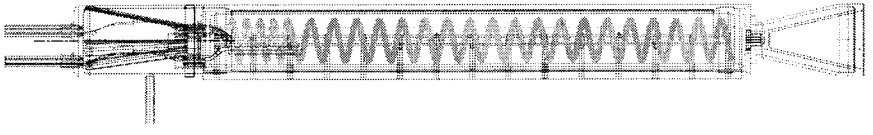
Goal: Provide instrument cooling from 30 K to 1.5 K with zero vibration and zero EMI using long life, low-power, low-mass coolers for long duration space missions.

Technical Challenges for NASA applications:

- Demonstrate reliability for 10 year mission lifetime by preventing degradation of sorbents and cryogenic systems during long-term operation.
- Demonstrate scalability to milliwatt cooling levels while maintaining power efficiency.
- Integrate cooling stages from 30 K to 1.5 K (metal hydride/H_2 to 9 K, carbon/He below 9 K).



Planck Focal Plane Cooling Schematic



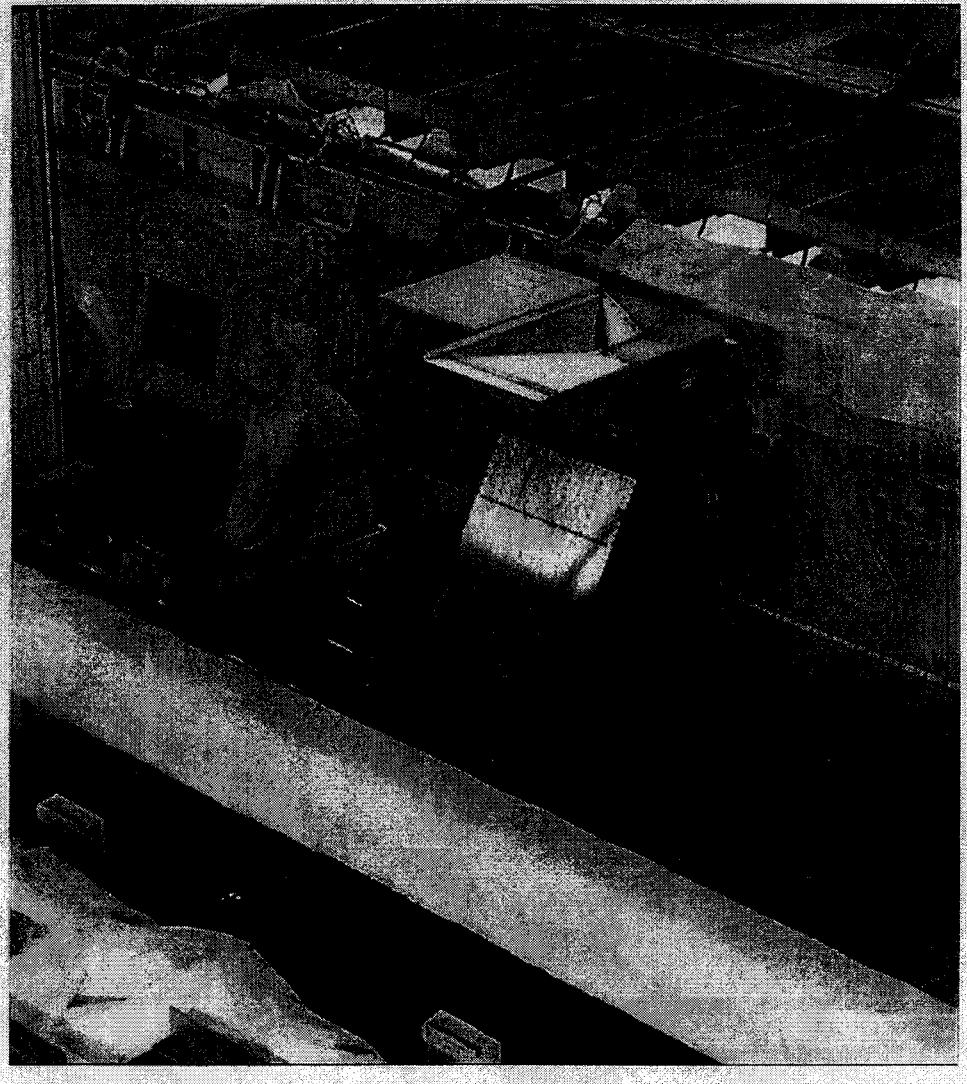
Metal-Hydride Compressor Element

Major Benefits:

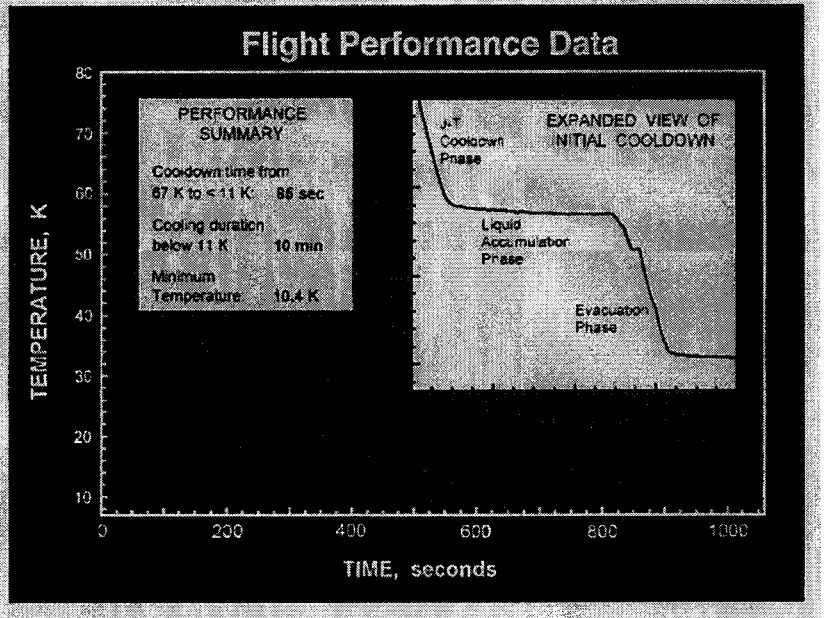
- Enabling technology for long-duration (~10 Years) missions requiring zero vibration, such as long-baseline interferometers.
- Elimination of expensive, massive dewars containing expendable cryogen.

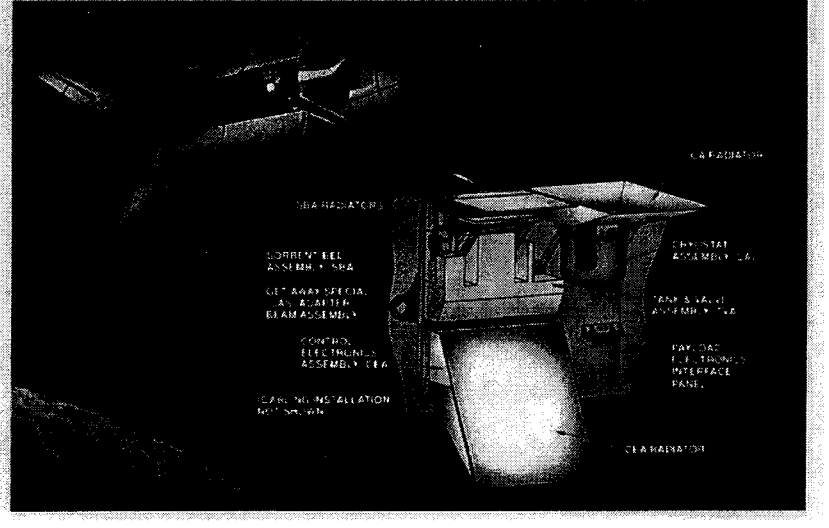
JPL

BETSCE 10 K SORPTION CRYOCOOLER FLEW SUCCESSFULLY ON STS-77, MAY 19-29, 1996



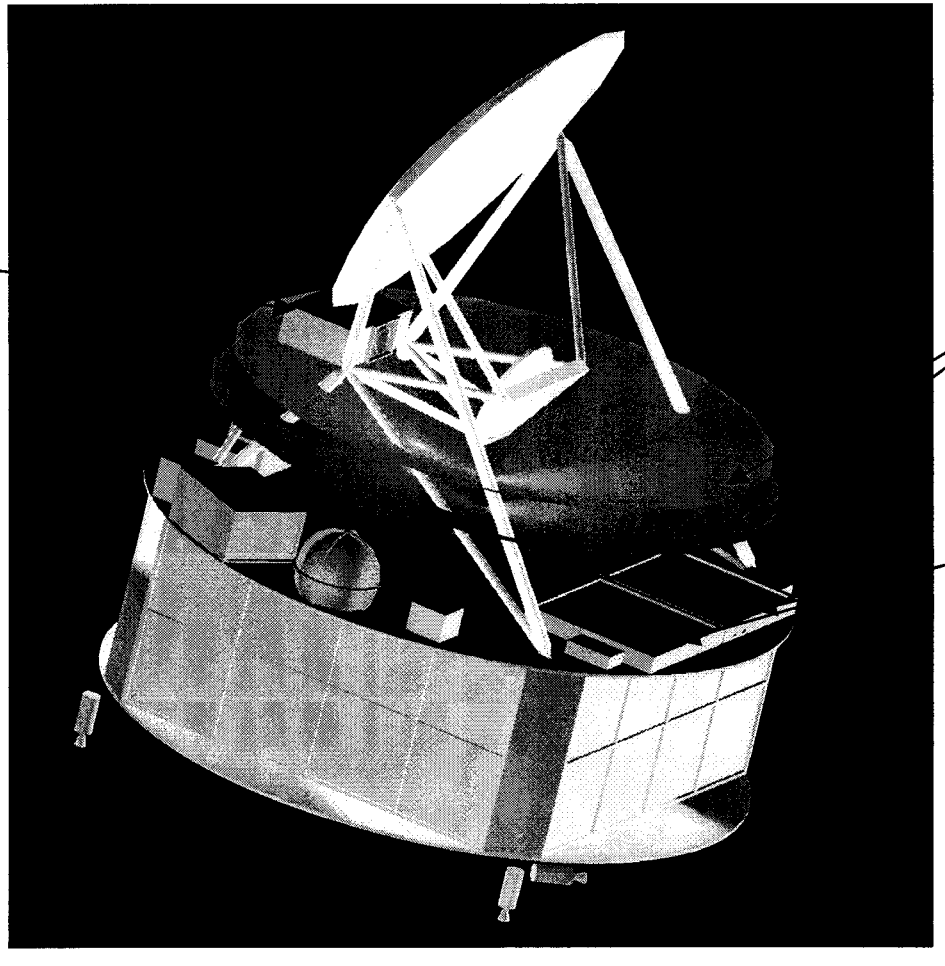
Brilliant Eyes Ten Kelvin Sorption Cryocooler (BETSCE) aboard Space Shuttle Endeavour





Planck Spacecraft

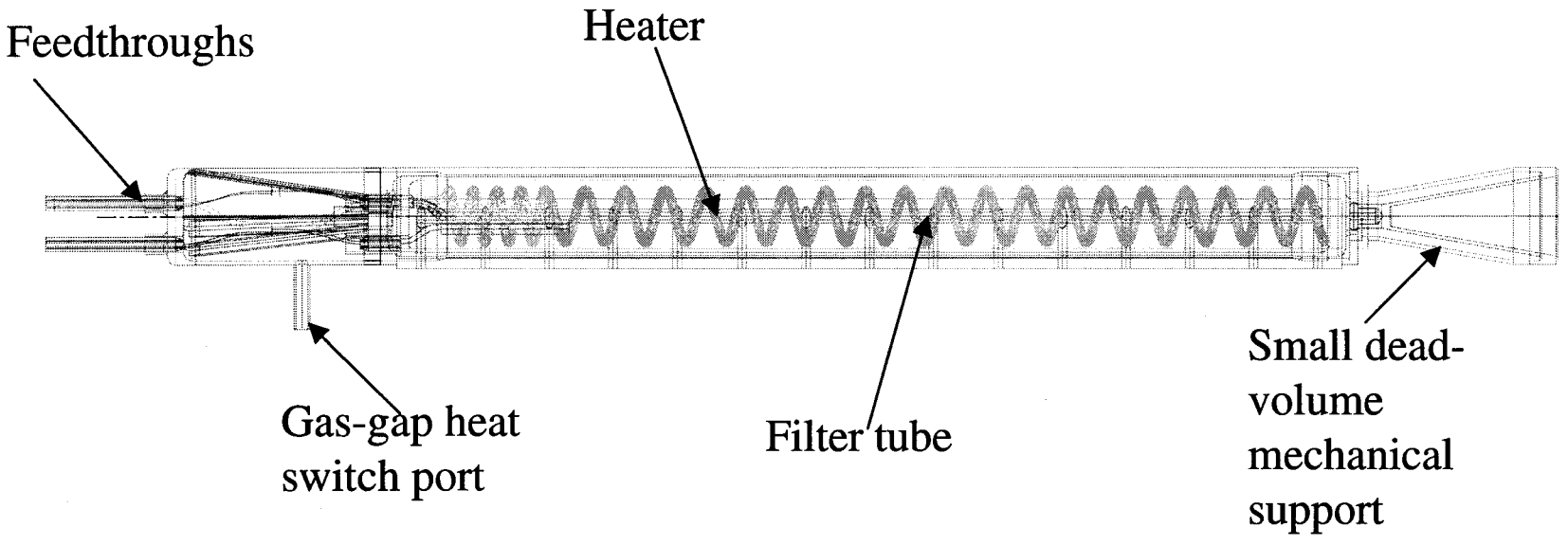
20 K combined focal plane assembly



V-groove radiators with low-emissivity facing surfaces provide passive precooling of the optical bench to 50 K.

20 K sorption cooler compressors reject heat at 280 K

Design Features of the Prototype Planck Compressor Sorbent Beds

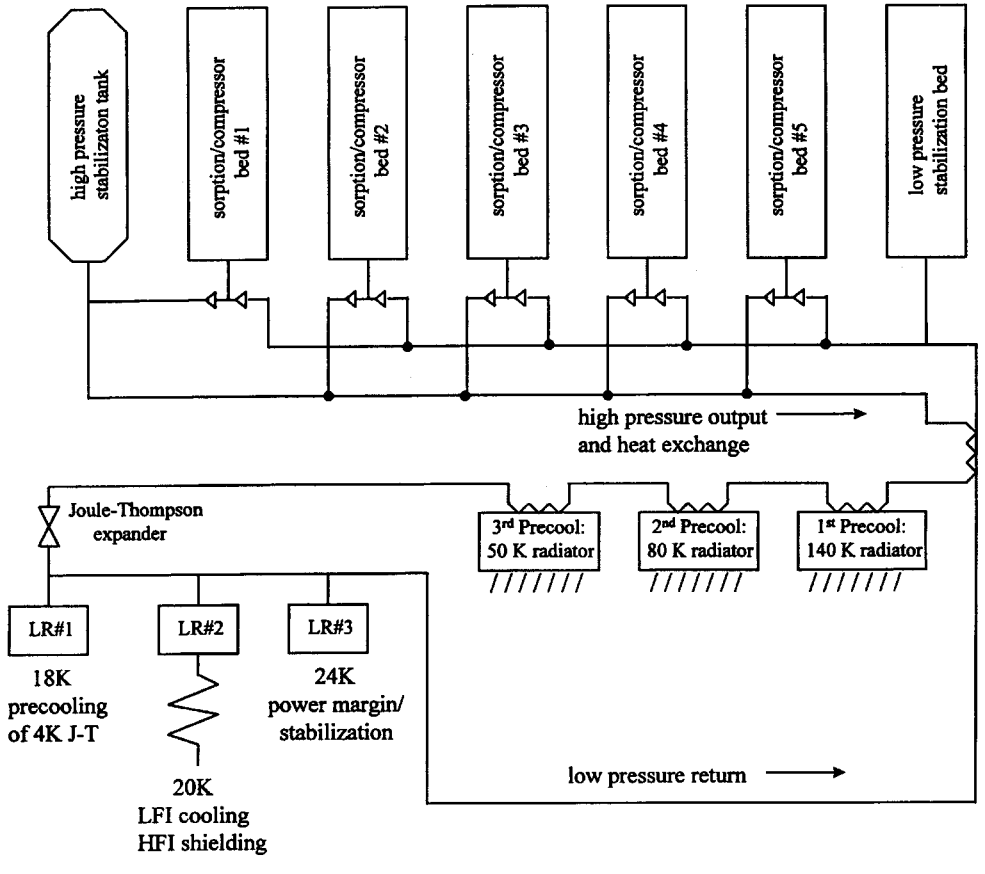


- Isolation of the beds from the radiator is provided by a hydrogen-sorption gas-gap heat switch.
- Gas flow from the hydride is facilitated by a porous filter tube - gas only needs to diffuse through the hydride along the radius.
- All components in contact with the hydrogen are made of 316L VAR electropolished stainless to avoid contamination of the hydride and degradation of materials due to contact with hydrogen.
- Temperature inside the bed is monitored by a thermocouple.

BETSCE - Flight Heritage

- Brilliant-Eyes Ten Kelvin Sorption Cooler Experiment flew in May 1996 on shuttle and demonstrated 10.4 K hydrogen sorption cooling.
- Verified that behavior of metal-hydride compressors on orbit is the same as on the ground.
- Also verified the ability to produce and retain liquid hydrogen reservoirs in microgravity.
- The failure of a valve due to particulate contamination demonstrated the need for extreme cleanliness in fabrication, and need for filters to protect valves.

Sorption Cooler Operation

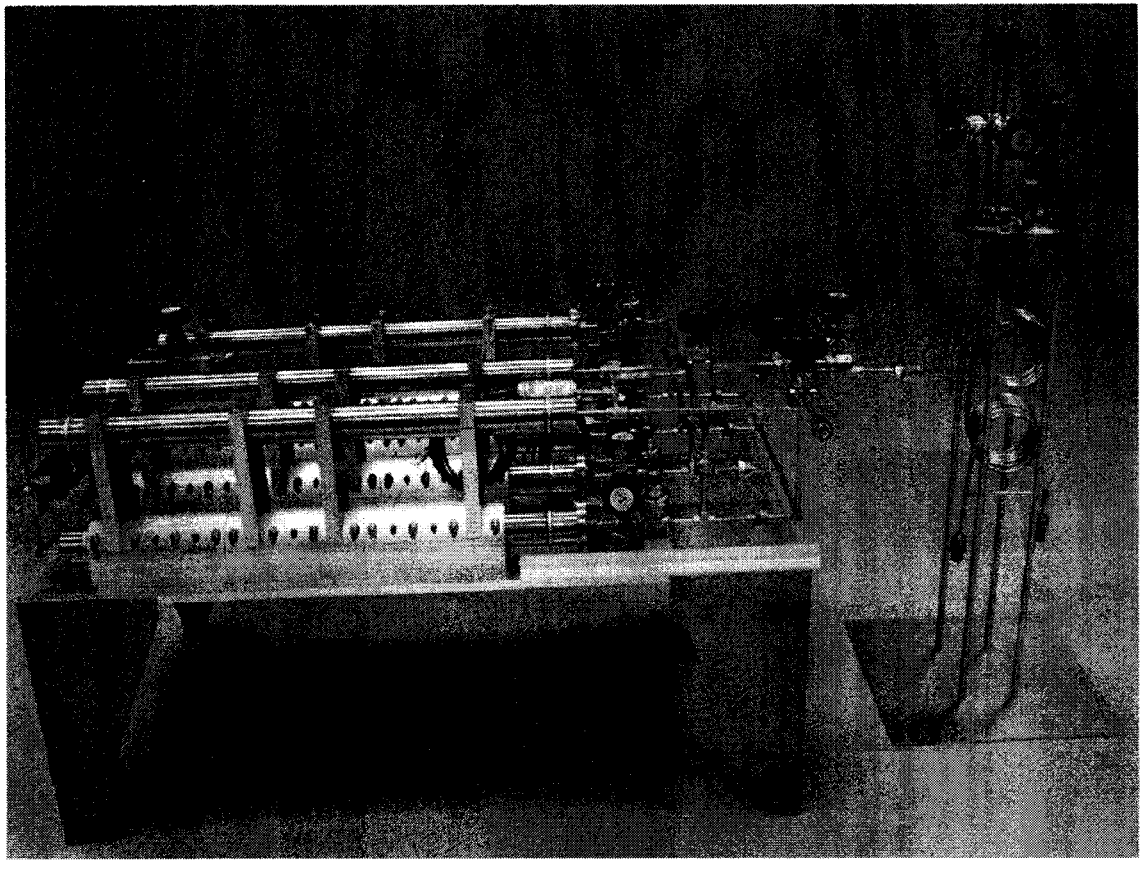


- Compressor beds are operated in periodically in a fixed sequence to provide continuous cooling.
- At any given time:
  - One bed is hot and desorbing
  - One bed is cooling down
  - Two beds are and adsorbing
  - One bed is heating up
- All control of flow is determined by bed temperatures and check valves. There are no actively controlled valves in the system.
- Compressor bed temperature is controlled by an on-off plus proportional controller.

Development Program for 20 K Sorption Coolers

- Develop 25 K continuous cooler for 25 K UCSB Flight
- Hydride Materials Characterization
- Development of prototype Planck compressor elements
- Development of brassboard Planck cryostat
- Development of prototype Planck cryostat
- Development of prototype 20 K Planck cooler with flightlike electronics
- Development of EM/QM/FS 20 K Planck cooler with flight electronics
- Development of two 20 K flight coolers for Planck

UCSB BEAST
25 K Single-Stage Sorption Cooler



This 25 K single-stage sorption cooler was built for the UCSB BEAST long-duration balloon flight experiments to measure the cosmic microwave background radiation.